HIGH FREQUENCY MAGNETIC FIELD ANTENNA

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

This invention was made with government support under Contract Number 116088 awarded by the National Institute of Justice. The government has certain rights in the invention.

CROSS-REFERENCE TO RELATED APPLICATIONS

Not applicable

THE NAMES OF THE PARTIES TO A JOINT RESEARCH AGREEMENT

Not applicable

INCORPORATION-BY-REFERENCE OF MATERIAL SUBMITTED ON A COMPACT DISC

Not applicable

BACKGROUND

1. Field of the Disclosure

This disclosure relates to a magnetic field antenna, in particular to a high frequency magnetic field antenna.

2. Description of Related Art

Digital television (DTV) utilizes broadcast television channel frequencies that historically were utilized for analog television channels. For example, VHF channels utilize frequencies in the range 54 MHz to 216 MHz while UHF channels utilize frequencies in the range 470 MHz to 890 MHz. Each channel occupies a band of frequencies known as channel bandwidth. While a single analog television program occupied one channel bandwidth, encoding techniques utilized in digital television allow programming multiple digital subchannels ("multicasting") and/or data within a single channel bandwidth.

The data included in a channel bandwidth may or may not be related to a television program. For example, "Datacasting" is the term used to describe the transmission of data unrelated to a television program that can be encoded into excess bandwidth associated with digital television signals. The excess bandwidth provides for data rates of about 2 Mb/sec and the data can be retrieved within a television station coverage area. Thus, Datacasting may be utilized to transmit data using digital television signals.

Mobile receivers may be configured to receive one or more television channels and to provide television program content and/or data to a user or user device. For example, mobile receivers may be included in or on a user vehicle (e.g., automobile), in a user device and/or coupled to a user device, e.g., computer (laptop, portable, tablet) and/or smart phone. Mobile receivers may be coupled to or may include a receive antenna configured to capture the transmitted television signal and to provide a corresponding electrical signal to the mobile receiver. Desirable characteristics of antennas used in the mobile environment include, but are not limited to a small form factor, broadband operating frequency range, receive pattern isotropic in the azimuthal plane and being physically durable.

The trend for broadcast television is to radiate only a horizontally-polarized signal rather than one that has been typically elliptically polarized. An antenna configured to capture an elliptically polarized electromagnetic wave (e.g., a television signal) may not necessarily capture a horizontally polarized electromagnetic wave. For example, a whip antenna (i.e., an electric field dipole antenna) that is typically oriented vertically may efficiently capture an elliptically polarized electromagnetic wave but may not reliably capture a horizontally polarized electromagnetic wave. Reliable capture generally requires capturing enough of an incident electromagnetic wave to produce a usable output. Since a whip antenna is vertically oriented, it is considered cross-polarized relative to an electric-field component of a horizontally polarized electromagnetic wave. In order to reliably receive a horizontally polarized electromagnetic wave (e.g., a digital television signal), an electric field antenna should be co-polarized, i.e., should be horizontally oriented. While horizontally oriented electric field antennas configured for mobile applications exist, they are relatively large (having a diameter or width between approximately 14 and 22 inches). Because of their size, they can be difficult to mount, are not suitable for handheld applications and may be insufficiently robust physically, e.g., may be frangible.

Television signals, as electromagnetic waves, include an electric-field component and a magnetic-field component. Thus, an alternative to using an electric field antenna to capture the electric-field component may be to capture the magnetic-field component using a magnetic field antenna such as a loop antenna. For example, some AM radio antennas are loop antennas configured to capture the magnetic-field component of a transmitted AM radio signal. For broadband reception, a loop antenna is configured to be electrically small with a circumference that corresponds to some fraction of a wavelength of a maximum operating frequency. For the AM band (531 kHz to 1.710 MHz), the maximum operating frequency is 1.710 MHz. For higher frequencies, the loop size is smaller since the loop circumference depends on the maximum operating frequency. The output voltage of a loop antenna corresponds to the captured magnetic-field component of a received electromagnetic wave and is proportional to loop size. Thus, a smaller loop size corresponds to a smaller output voltage.

The output voltage produced by a loop antenna may be increased (i.e., gain) by adding turns and/or wrapping the loop antenna around a ferrite material. Use of these techniques has been generally limited to relatively low frequencies, e.g., the AM radio band. Adding turns increases the inductance of the loop antenna. At higher frequencies, the increased inductance results in an extremely large antenna output impedance, thereby making coupling highly inefficient. Further, the increased inductance can lead to resonant behavior within the operating frequency range, negating wideband performance of a loop antenna. The ferrite material is configured to provide gain to the loop antenna and the amount of the gain is based, at least in part, on magnetic properties of the ferrite material. However, these magnetic properties are frequency dependent and, historically, ferrite materials had poor magnetic properties at higher frequencies thereby providing no gain at higher frequencies.

SUMMARY

The present disclosure relates in one embodiment to an antenna system. The antenna system comprises a loop antenna comprising a conductor; and a magnetic gain element positioned in an aperture defined by the loop antenna, the magnetic gain element comprising a magnetic material that has a relative permeability greater than one for an operating